High Resolution Spatial Estimates of Average Snow Density and Snow Water Equivalent from Differenced LiDAR Elevations and GPR Travel-Times at Grand Mesa, Colorado

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ABSTRACT

Pit, ground based radar, and airborne LiDAR observations of the snowpack were acquired throughout the SnowEx 2020 intensive observation period at Grand Mesa, Colorado. We developed a method for automatically determining the ground-penetrating radar (GPR) wave two-way travel-time for the reflection off of the ground through the snow cover. Our method uses the maximization of the coherence between co-polarized and cross-polarized GPR channels. We validated the accuracy of these travel-time picks by comparing the snow depth measured by differencing the snow-on and snow-free airborne LiDAR acquisitions to the snow depth estimated from the GPR travel-times and the average density of nearby snow pits which were converted to radar wave speed (R = 0.67, RMSE = 12 cm). To extend this result, using multivariate linear regression, we developed a model that, once trained using the LiDAR and GPR derived snow density, predicts the average snow density within the domain of the LiDAR acquisition without dependence on GPR travel-times. The modeled density shows intriguing spatial variability that agrees well with the spatial observations of average snow density from the LiDAR-GPR method (R = 0.75, RMSE = 22 kg/m^3). Using the modeled densities and the LiDAR measured snow depths, we estimated the snow water equivalent (SWE), and found good agreement with the SWE measured at 96 snow pits within the LiDAR domain (R = 0.73, RMSE = 39 mm).

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